

However, if the frequency of copulations resulting in the transfer of two spermatophores in the laboratory is a good estimate of their frequency in the field (3/199 copulations observed in the laboratory), its quantitative effect should be small.

Spermatophores always leave recognizable remains within the corpus bursae of the female. This is not true in *C. xami* since in the laboratory it was not always possible to observe clear spermatophore remains in very old females that had laid most of their eggs (pers. obs.). However, judging from wing wear, no female in this condition was sampled (see paragraph four above).

In conclusion, the possible violation of the first and the last assumptions, and the fact that some of the females may have mated again had they not been collected, results in an underestimation of the frequency of copulations in females; whereas the fact that some males transfer more than one spermatophore in one copulation results in an overestimation of the number of copulations. However, judging from the low frequency of "interrupted" copulations (4.4%), very worn females in the field (at least during the sampling period), and copulations resulting in the transfer of two spermatophores (1.5%), I conclude that spermatophore counts are a reasonably good estimate of female copulation frequency in *C. xami*.

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ADDITIONAL NOTES ON *PROSERPINUS CLARKIAE* AND *ARCTONOTUS LUCIDUS* (SPHINGIDAE) LIFE HISTORIES FROM THE PACIFIC COAST OF NORTH AMERICA

Additional key words: Onagraceae, Rubiaceae, *Gayophytum*, *Galium*, *Clarkia breweri*, *Clarkia modesta*, *Camissonia*.

Host associations for *Proserpinus clarkiae* (Boisduval) and *Arctonotus lucidus* (Boisduval) have recently been documented. *Proserpinus clarkiae* was found using *Clarkia unguiculata* (Lindley) in nature (Osborne 1995). Here, I compare results of my life history work on *P. clarkiae* with other results (Hardy 1959) on this species. The life history of *A. lucidus* is also known (Comstock & Henne 1942). However, the first natural host associations for *A. lucidus* were made by photographs and collections from *Clarkia* species in California, and are presented here along with observations on captive rearing of this moth. The immature stages of these related sphingid species have been confused in the field by some, possibly due to their sympatry, common use of *Clarkia* hosts, and superficial resemblance. Thus, I will also discuss morphological differences among these and other sympatric *Clarkia* feeding sphingids.

In presenting the biology of *P. clarkiae* (Osborne 1995), I repeated the assertion made by Hodges (1971) that its life history was unknown. Since that time, Dr. Frederick Rindge (American Museum of Natural History) has drawn my attention to a life history of *P. clarkiae* that predates both works. Larvae and a pupa reared from Vancouver Island (Hardy 1959) were described by Hardy (1959), and match the immatures of *P. clarkiae* from California. Hardy obtained seven ova by confining females over potted *Galium aparine* (Lewis & Szweykowski) (Rubiaceae). He reared at least one individual to pupation on that plant, but a field host was not given. The single fifth instar larva of *P. clarkiae* from Vancouver Island had the lateral dark blotches contiguous in an undulating line, a trait consistent

with some (< 5%) of the California material I reared (most California larvae had oblique blotches disjunct) (Osborne 1995). This dark form may be typical of cool, wet, north coastal localities, where darker maculation may impart local selective advantages, or may be an artifact of captive rearing.

Dr. Robert Raguso, who studied sphingid pollination of *Clarkia* species in central California (see Raguso & Pichersky 1995, Raguso et al. 1996, Raguso & Light 1998), sent me several suspected *Proserpinus* larvae, a reared pupa, and a photograph (Fig. 1) of a fifth instar larva in nature on *Clarkia breweri* (A. Gray) E. Greene. These specimens were all collected from *C. breweri* and *Clarkia modesta* (Jepson) at Del Puerto Canyon, Stanislaus Co., California in May, 1991. However, instead of *P. clarkiae*, all were determined (by KHO) to be *Arctonotus lucidus*, a closely related species from a monotypic genus. Early instar *A. lucidus* larvae may be separated from *P. clarkiae* by the presence of a black anal horn which is absent in *P. clarkiae*. Fifth instar *A. lucidus* lose the anal horn, but have dorsal and lateral markings of olive green (but briefly black just after molt [Comstock & Henne 1942]), not black or gray as in *P. clarkiae*. In addition, *A. lucidus* can be distinguished from *P. clarkiae* on the basis of dorsal, transverse intersegmental lines of tan or cream breaking the olive green field, and ventral whitish or gray. The ground color in fifth instar *A. lucidus* larvae is variable (Comstock & Henne 1942), ranging from black to olivaceous green to light green, to pink (Comstock & Henne 1942; D. Rubinoff pers. comm.; K. H. Osborne unpubl. obs.).



FIG. 1. Fifth instar *Arctonotus lucidus* larva on *Clarkia breweri* at Del Puerto Canyon, Stanislaus Co. CA., May, 1991. Photograph by Robert Raguso.

Raguso's photograph of an *A. lucidus* larva on *C. breweri*, and collections of *A. lucidus* from *C. breweri* and *C. modesta*, represent the first natural host records for this moth. Raguso (pers. comm. 1995) has seen [these?] larvae on *Clarkia gracilis sonomensis* (Hitche.) near Lake Berryessa, Napa Co., California. (These records must be considered as likely *A. lucidus* but could possibly be *P. clarkiae*.) Additionally, one wandering fifth instar *A. lucidus* (determined by KHO) was found by M. Lynn (pers. comm.) in May, 1997 in the immediate vicinity of abundant *Camissonia bistorta* (Nutt.), *Camissonia strigulosa* (Fisk. & Meyer) Raven [= *Oenothera contorta* Munz], and *Clarkia purpurea* (Curt.) Nels. & Macbr. at Lake Skinner, Riverside Co., California, suggesting these plants as possible hosts. The *Camissonia* species are used as larval hosts by related sphingids in southern California, *Euproserpinus phaeton* Grote & Robinson using *C. bistorta* (Osborne 1995), *Euproserpinus euterpe* Hy. Edwards using *C. strigulosa* (Tuskes & Emmel 1981, K. H. Osborne unpubl. obs.), and *Hyles lineata* (L.) using both (K. H. Osborne unpubl. obs.). *Clarkia breweri* is restricted to central California from Alameda Co. south to Fresno Co. (Munz 1959) and *C. modesta* ranges through California from Tehama Co. south to Santa Barbara Co. (Hickman 1993). The wide range of *A. lucidus* (Holland 1903, Hodges 1971) from British Columbia at least as far south as San Diego Co., California (Brown & Donahue 1989; Osborne unpubl. obs.) indicates *A. lucidus* must use other host plant species.

Galium, suitable for *P. clarkiae* in captivity (Hardy 1959), was rejected by *A. lucidus* as were two unnamed *Oenothera* species (Comstock & Henne 1942). In captivity, *A. lucidus* larvae would accept leaves of *C. breweri*, *C. modesta* and *Clarkia affinis* (H. Lewis & M. Lewis) (Raguso pers. comm.), but were hesitant to accept *Clarkia*

unguiculata (Lindley) and *Fuchsia* (K. H. Osborne unpubl. obs.; Raguso pers. comm.). Most prepupal *A. lucidus* larvae wandered and died without pupating in dry, sandy soil, and the one that did pupate, about 3 cm below ground in loose gravel, was attacked by mold and never emerged (K. H. Osborne unpubl. obs.; Raguso pers. comm.). Dan Rubinoff (pers. comm.) reported success getting *A. lucidus* to pupate on moist potting soil and when reared by Comstock & Henne (1942) larvae pupated as deep in the soil as possible (in cages).

Hyles lineata is common on *Clarkia* (*C. unguiculata* at Gates Canyon, Solano Co, CA [unpublished records] and *C. breweri*, at Del Puerto Canyon [Raguso]) when *A. lucidus* and *P. clarkiae* may be present. *Hyles lineata* is easily distinguished from larvae of *A. lucidus* and *P. clarkiae* by its prominent orange or yellow anal horn in all larval stages and by distinctive (but variable) longitudinal markings (Hodges 1971).

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